CFBC BOILERS IN CHINA– PRESENT AND FUTURE

Jiang Minhua
Vice President, Thermal Power Research Institute
State Power Corporation of China

ABSTRACT

The status of circulating fluidized bed combustion (CFBC) boilers in China is introduced in this paper. Some problems encountered in CFBC boiler applications are pointed out, such as high N_2O emissions, difficulties in ash utilization, and low combustion efficiency when burning low-volatile coals. In spite of these problems, CFBC boilers still have a bright future due to several beneficial operating features. This paper suggests ways to take greatest advantage of these features, and to avoid problems that compromise performance. In addition, some features of a new type of CFBC boiler are briefly discussed.

INTRODUCTION

China relies mainly on coal for its power generation, and coal quality differs greatly from one place to another. To use low-quality coals (those with high ash and high moisture contents, but low calorific value or low volatile matter), China in the 1970s developed various kinds of bubbling fluidized bed combustion (BFBC) boilers with unit steam outputs ranging from 10 to 130 tons per hour (t/h). More than 3000 BFBC boilers were in operation in the 1980s burning different kinds of low-quality coals, but at low efficiency.

In order to use low-quality coals efficiently, China turned to CFBC boilers in the mid-1980's. CFBC unit capacity was still small, usually ranging from 6 MW to 12 MW. In the first stage of development, CFBC boilers were unreliable because of heavy erosion to tube metals and refractory components, and an inability to reach rated outputs due to improper design of circulating ash separators, etc. After more than 10 years of improvement by manufacturers and operators, small-capacity CFBC boilers now operate reliably and efficiently, even when very low-quality coals are used. The remaining problem is that none of those boilers is designed with limestone desulfurization.

As for medium-sized CFBC boilers (50 MW, steam output 220 t/h), some Chinese manufacturers have purchased licenses from abroad and imported several boilers. Most of these boilers operate well, and some are equipped with limestone desulfurization systems. In addition, some Chinese manufacturers are now developing 50-MW CFBC boilers. A 50-MW CFBC boiler designed jointly by the Thermal Power Research Institute (TPRI) and Jinan Boiler Works is now under construction and will be put into operation soon.

In order to hasten use of CFBC boilers in its power sector, China launched a demonstration project at Neijiang Power Plant in Sichuan Province. A 100-MW CFBC boiler was imported from a Finland company to determine whether the boiler could efficiently and cleanly use Chinese coals with low volatile matter and high sulfur content. The project was successful in most aspects, and in recent years, some Chinese manufacturers purchased licenses from abroad or developed their own technologies and began to produce 100-MW CFBC boilers.

Because China's power industry developed very quickly in the last decade, SO_2 and NOx emissions became a big problem. Using CFBC boilers is thought to be a practical way to

solve both SO_2 and NOx pollution problems. As the majority of Chinese power units are now 300-MW ones, SPC plans to set up a 300-MW CFBC demonstration unit.
Use of CFBC boilers in China has shown the boilers' unique performance capabilities and problems, which are discussed in the following sections.

ENVIRONMENTAL EFFECTS OF CFBC BOILERS

The demonstration project at Neijiang Power Plant showed that CFBC boilers can have low SOx emissions when limestone is added into the furnace as a desulfurization sorbent, and low NOx emissions when furnace temperatures are in the range of 850–900 C. Table 1 lists a set of operation data for the boiler.

Table 1. Operating data for 100-MW CFBC boiler at Neijiang Power Plant

Sulfur content	3.68%
Ca/S molar ratio	2.219
SOx emission	684 mg/m^3 (dry, O_2=6%)
NOx emission	78 mg/m^3 (dry, O_2=6%)
CO emission	211 mg/m^3

A desulfurization efficiency of 90% can be reached in most existing CFBC boilers with limestone systems, while NOx formation can be controlled by low-temperature combustion. However, low-temperature combustion causes formation of N_2O. Figure 1 shows the test results of NOx and N_2O emissions from a 1-MW CFBC pilot plant in TPRI. NOx emissions (mainly NO) decrease as the bed temperature decreases, while N_2O emissions increase at the same time. The N_2O emissions caused by low-temperature combustion may hinder further use of CFBC boilers. Fortunately, N_2O emissions from big CFBC boilers are much lower than those from the pilot plant (See Fig.2).

ECONOMICAL PERFORMANCE OF CFBC BOILERS

CFBC boilers can be designed to burn various kinds of coals, a unique advantage of this kind of boiler. However, this advantage does not mean that existing CFBC boilers are able to burn all kinds of coal. CFBC boilers should be designed according to the properties of coal they will burn, especially when burning coals with low volatile matter. TPRI has carried out many tests on coal combustion in its CFBC testing facilities, and in other boilers (including the 100-MW boiler at Neijiang). The tests have shown that the CFBC boilers fail to reach the combustion efficiency as reported when burning low volatile coals. The unburned carbon content usually is more than 13% in the Neijiang boiler, but fell to 8 or 9% during adjustment testing conducted by TPRI. The most effective way to raise combustion efficiency is to raise the bed (combustion) temperature and improve air distribution inside the furnace. Raising the solids recirculation or fly-ash re-injection has only a minor effect on combustion efficiency. However, increasing the bed temperature is confined by the best desulfurization temperature range.
CFBC boilers have another unique property: the ability to operate stably at very low loads without support oil or gas. The 100-MW boiler at Neijiang is able to operate at 30% of full load without support oil, but its load-change rates fail to reach the values expected for the design. Although CFBC boilers are able to operate at low loads, doing so economically is still a problem; the boilers already feature low-temperature combustion,

which leads to even lower combustion temperatures under low loads (see Fig.3). This results in lower combustion reactivity, lower combustion efficiency, higher unburned carbon content in fly-ash, and more difficulty in ash utilization; this problem must still be solved.

FUTURE APPLICATIONS FOR CFBC BOILERS

Considering China's coal resources and the demands of its power sector, CFBC boilers will be used in the following ways, as well as for environmental purposes:

- as peak load operation units: peak load operation has become more and more important for Chinese power plants in recent years, but requires large capacity units; CFBC boilers are suitable for this role.
- for burning hard-to-use coals: coal properties change greatly from one place to another in China; coal from some areas is hard to burn, while coal from other areas may tend to slag. CFBC boilers can help power plants avoid these problems.
- to solve other power generation problems: some power plants suffer from problems such as furnace slagging, fouling and unstable firing for which CFBC boilers could be a solution.
- to serve as supercritical units: the even distribution of furnace temperatures in CFBC boilers provides favorable conditions under which to adopt supercritical parameters.

A NEW TYPE OF CFBC BOILER

TPRI has proposed a new type of CFBC boiler for future application in Chinese power plants. The new boiler will be used for purposes other than desulfurization, and will have the following features:

- no limestone added for desulfurization (if desulfurization is needed, conventional flue gas desulfurization (FGD) can be used);
- bed temperature over 950 C but 50 C lower than coal ash softening temperature;
- lower bed pressure and less loss of air-distributor pressure reduces power consumption; and,
- ash circulation is controllable for keeping the proper bed temperature at any load.

Furthermore, the new type of boiler will have the following advantages:

- High combustion efficiency and low unburned carbon content in fly ash: due to higher bed temperature, combustion will be accelerated, combustion efficiency raised, and unburned carbon content in fly ash lowered.
- Economical operation at low loads: because the bed temperature can be kept high enough for complete combustion at low loads, combustion efficiency will be high and the carbon content in fly ash kept at an acceptable level for ash utilization.
- Easily used ash: because the carbon content in fly ash is low and no limestone is added with coal, the composition of solid residuals (bed ash and fly ash) will be steady, and both bed ash and fly ash will be easy to use.
- Much lower NOx emissions: in addition to being controlled by regulations, NOx emissions will be low in CFBC boilers because combustion temperatures will be much lower than in pulverized coal (PC) boilers.
- Reduced N_2O emissions: because the combustion temperature is much higher than in conventional CFBC boilers, N_2O emissions will be much lower.

- Power consumption equal to that of PC boilers: the increase in power consumption for air draft will be saved in coal preparation.
- Operating versatility: because this type of boiler will be more flexible for load changes than PC boilers and even conventional CFBC boilers, it will be suitable for peak load operation.
- Coal-burning flexibility: this type of boiler will be able to use hard-to-burn coals, and will be less effected by changes in coal properties.

CONCLUSION

CFBC Boilers in China are growing in capacity, and will be used in many ways in addition to desulfurization.

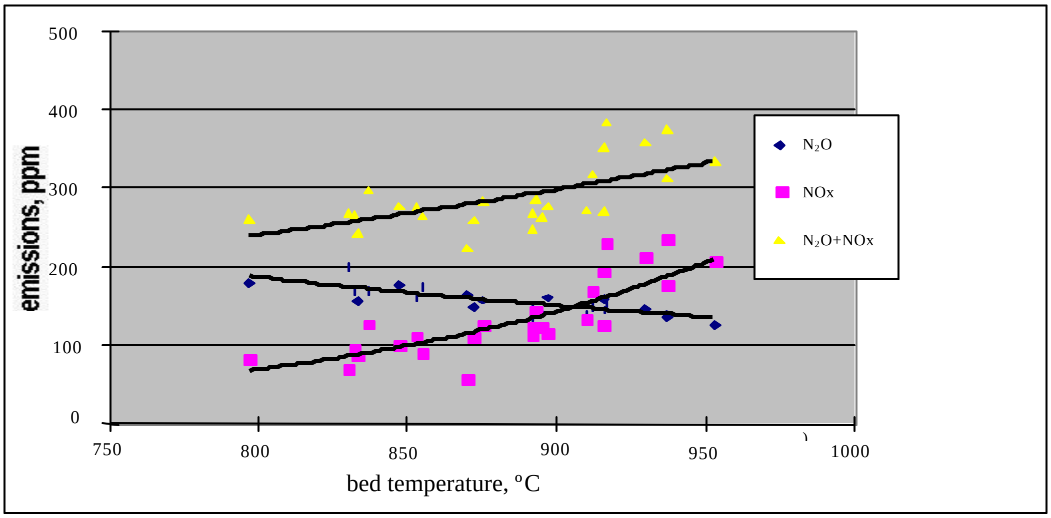

Figure 1. Nitrogen oxide emissions from a 1-MW CFBC pilot plant

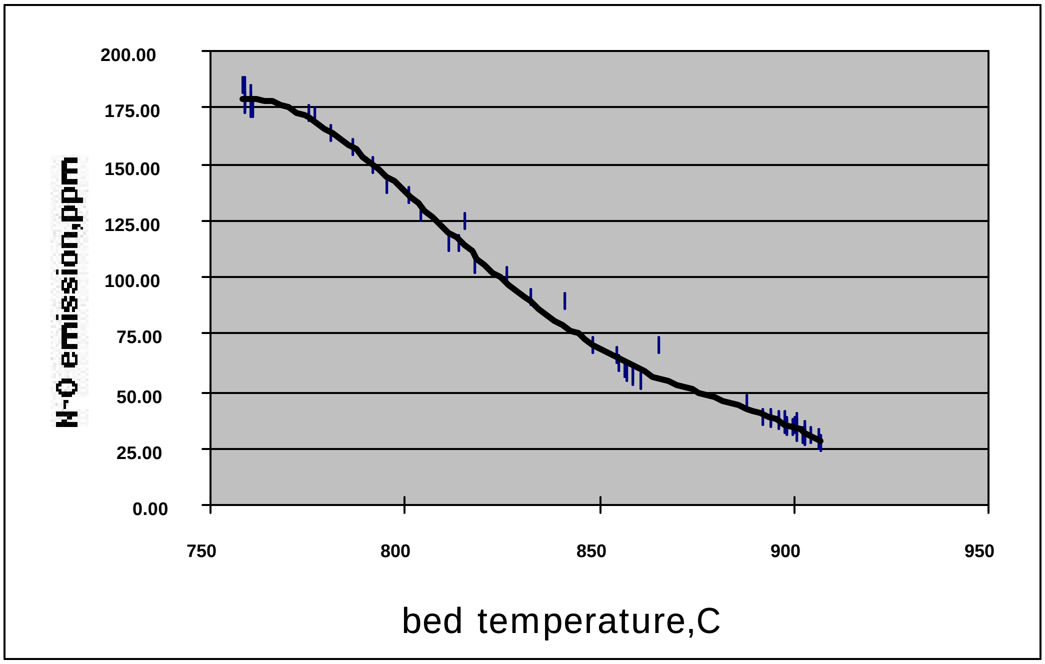

Figure 2. N_2O emissions from a 100-MW CFBC boiler

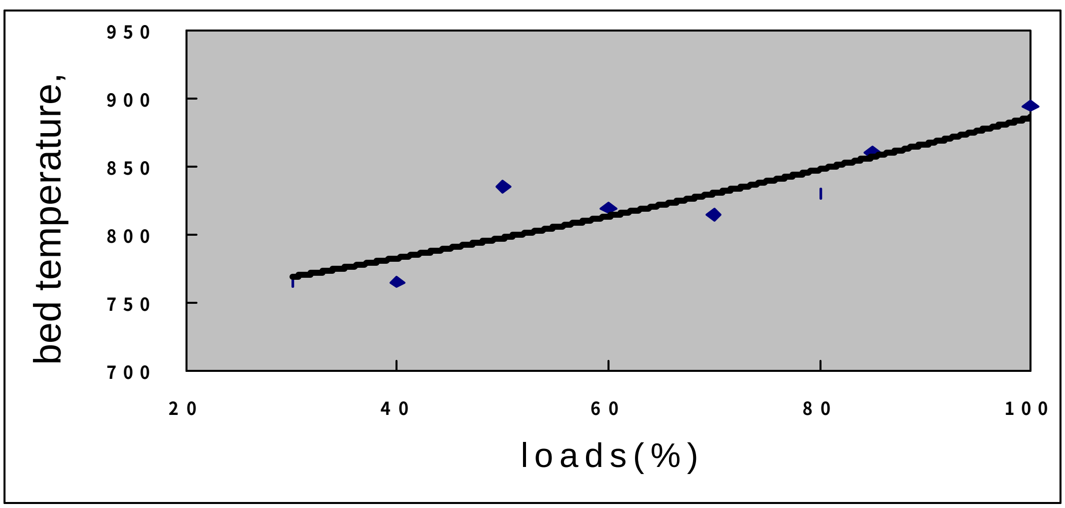

Figure 3. Relationship of bed temperature with loads of an existing boiler